Effects of Lower Frame Rates in a Remote Tower Environment

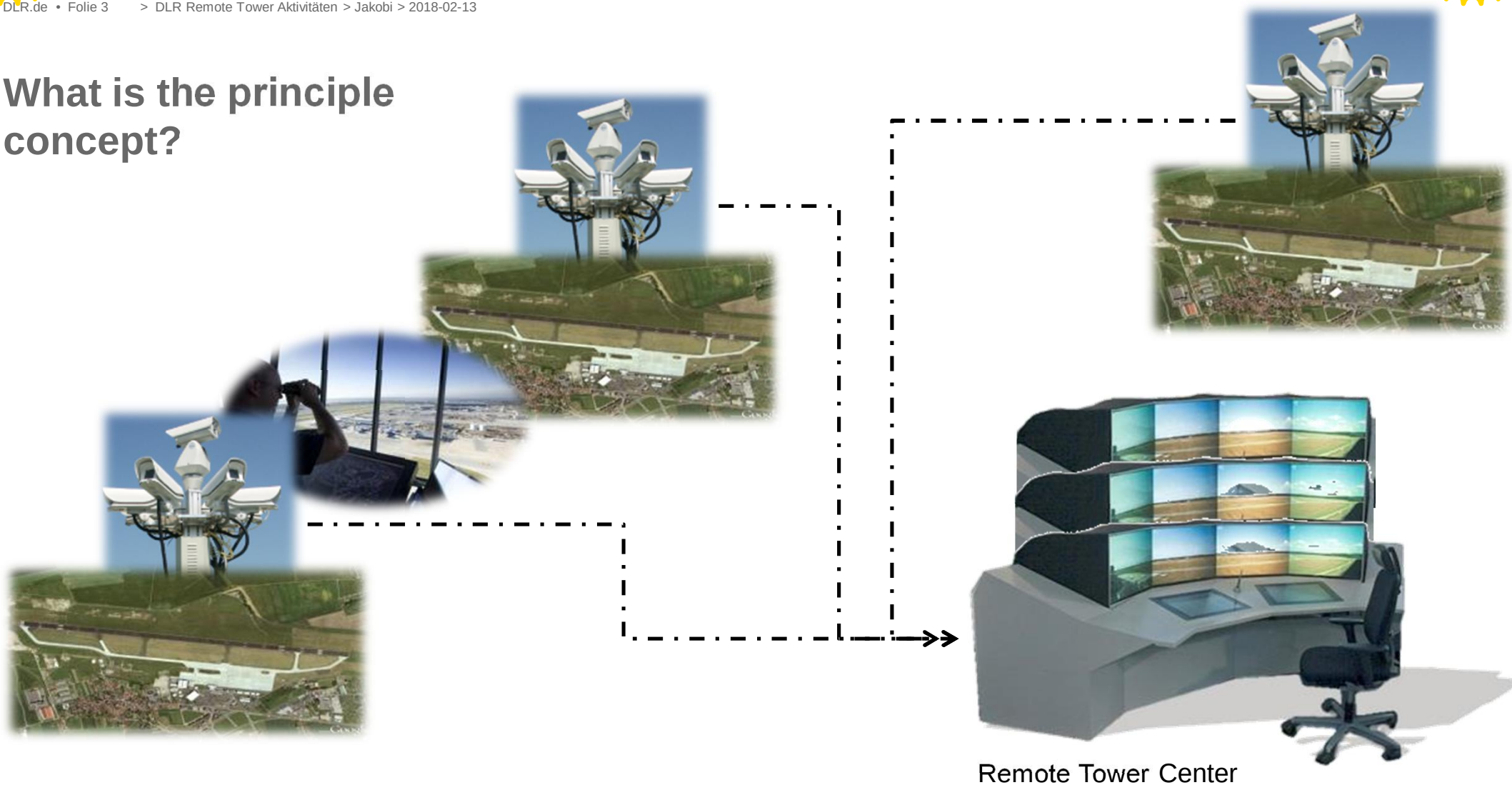
Jörn Jakobi (DLR)
Maria Hagl (Uni Grenoble)

DLR German Aerospace Center e.V.

The Vision 2002

- Virtual Tower Control -

What is the principle concept?

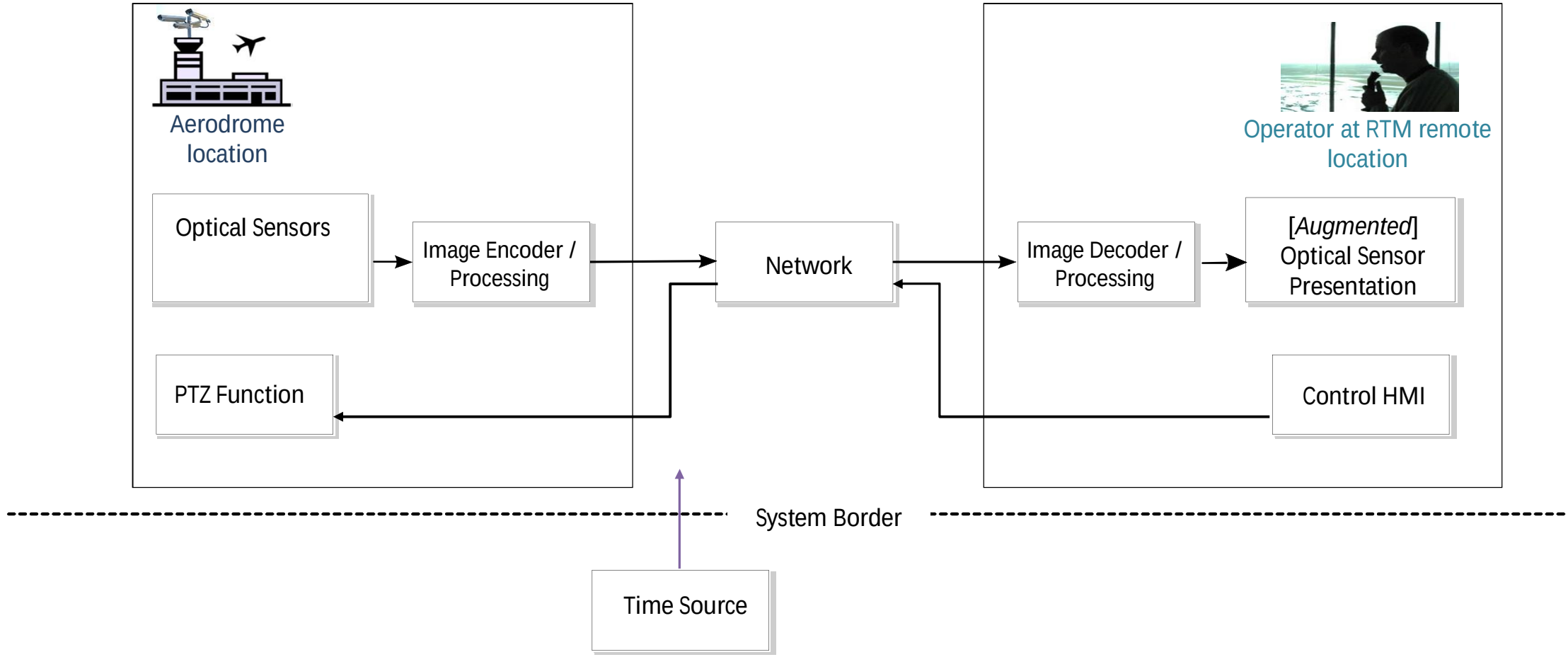


What is the benefit of Remote Tower?

- **Cost Savings**!
  - Cost efficient allocation of personell by relatively small investment
- **Maintained or even increased Safety!** by
  - Hot Spot Camera
  - Cameras beyond visible spectrum (e.g. IR)
  - Augmented Vision
    - Video Tracking, Weather, Scenery, etc.

➔ **Sustainability of cost efficent Airports and Air Traffic Services**

System Architecture



Factors contributing to Bandwidth

Horisontal x Vertical	Pixels per radians^2	Bits per pixel	Frames per sec	Compression - Standard - Factor

Our solution

360°x60°	0.28 mrad = Eye Resolution	12 bits/pixel	5 fps	H.265 1:125

87 Mpixels x 12 bits/px x 5 fps x 1:125 = ~40 Mps

Other solutions

360°x45° 360°x60°	Low:14 HD cam High: 39 HD cam	12 bits/pixel	30 fps	H.265 1:125

Low res/FoV: 28 Mpixels x 12 bits/px x 30 fps x 1:125 = ~80 Mps
High res/FoV: 87 Mpixels x 12 bits/px x 30 fps x 1:125 = ~250 Mps

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Research questions

What are the effects of low frame rates on:

- Visual Detection Performance
- Physiological Stress
- Perceived Video quality
- Perceived System operability

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Set up

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Test Design

80 min Real Life Traffic sample was recorded, which is varied over 4 different framerates

Participant ID-Code	Video 1	Video 2	Video 3	Video 4
M I T H 7 8	5 fps	10 fps	2 fps	15 fps
___ ___ ___ ___ ___ ___	10 fps	2 fps	15 fps	5 fps
___ ___ ___ ___ ___ ___	2 fps	15 fps	5 fps	10 fps
___ ___ ___ ___ ___ ___	15 fps	5 fps	10 fps	2 fps
___ ___ ___ ___ ___ ___	5 fps	10 fps	2 fps	15 fps
___ ___ ___ ___ ___ ___	10 fps	2 fps	15 fps	5 fps
___ ___ ___ ___ ___ ___	2 fps	15 fps	5 fps	10 fps
___ ___ ___ ___ ___ ___	15 fps	5 fps	10 fps	2 fps

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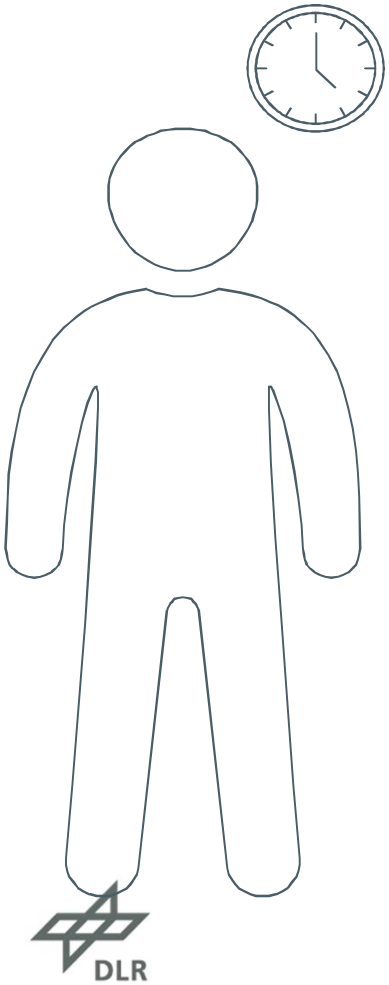
DLR Field Test Platform

schedule



Start	End	Schedule	Duration
08:45	09:00	Briefing + Participant Agreement + Questionnaire SSQ base	00:15
09:00	10:30	Video Experiment 1 + Questionnaire SSQ/PQ 1 + Pause	01:30
10:40	12:10	Video Experiment 2+ Questionnaire SSQ/PQ 2+ Pause	01:30
12:10	13:00	Lunch	00:50
13:00	14:30	Video Experiment 3 + Questionnaire SSQ/PQ 3 + Pause	01:30
14:40	16:15	Video Experiment 4 + Questionnaire SSQ/PQ 4+ DQ	01:35
16:15	16:30	Debriefing	00:15

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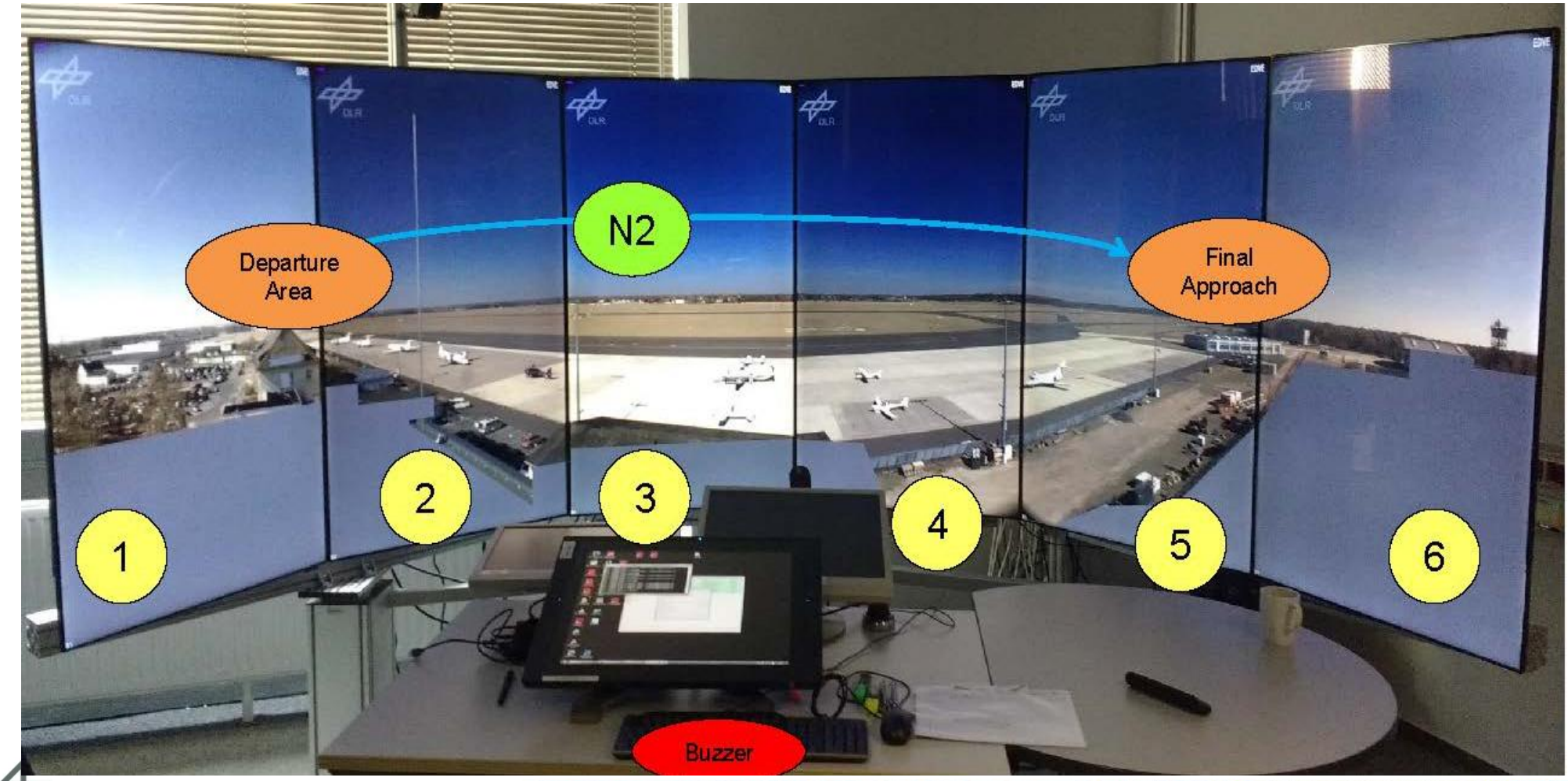
RTM of the DLR Field test platform Braunschweig



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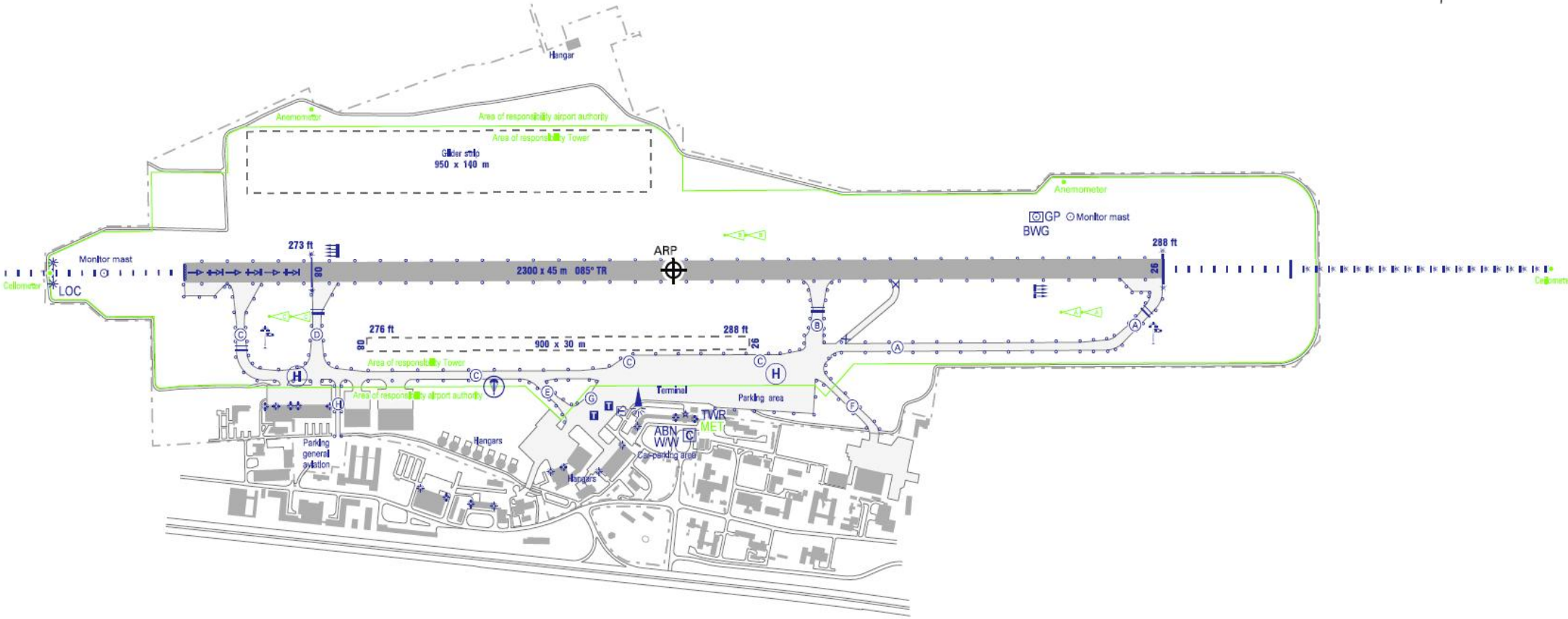
Airport, platform and environment specifications

Designation and lateral limits	CTR Braunschweig
Vertical limits	2200 ft MSL
Airspace classification	D
Language(s)	English, German
visibility	CAVOK without any clouds
wind	calm western winds
Local time	12:20 to 14:00, March 2017
Camera resolution	2 arc min
displays	6 x (1920x1080), 240° x 66°, 12bit/pixel, 55inch
Jitter	< 50ms
Distance to the screens	about 2,1m

Braunschweig Airport Map



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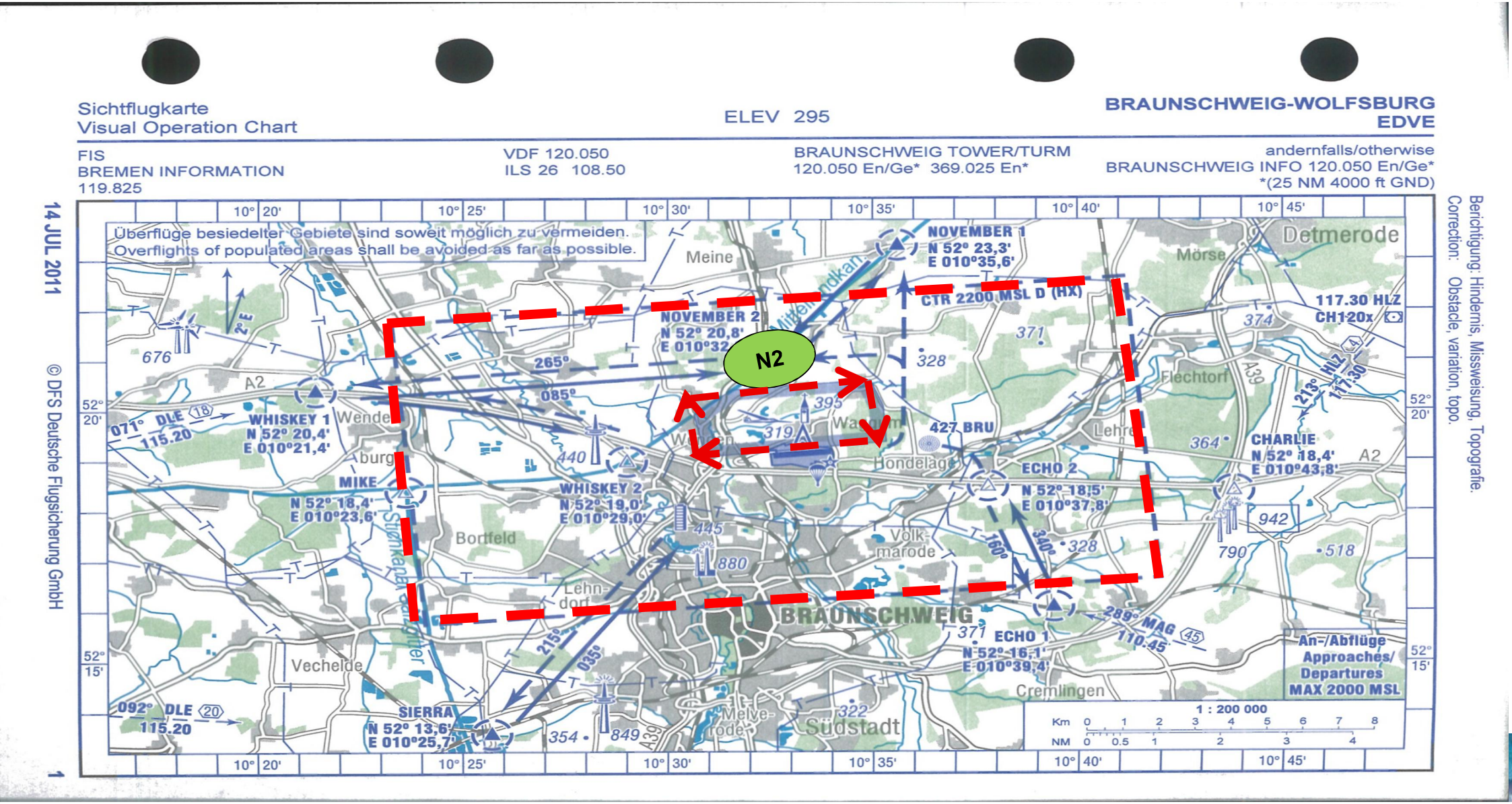
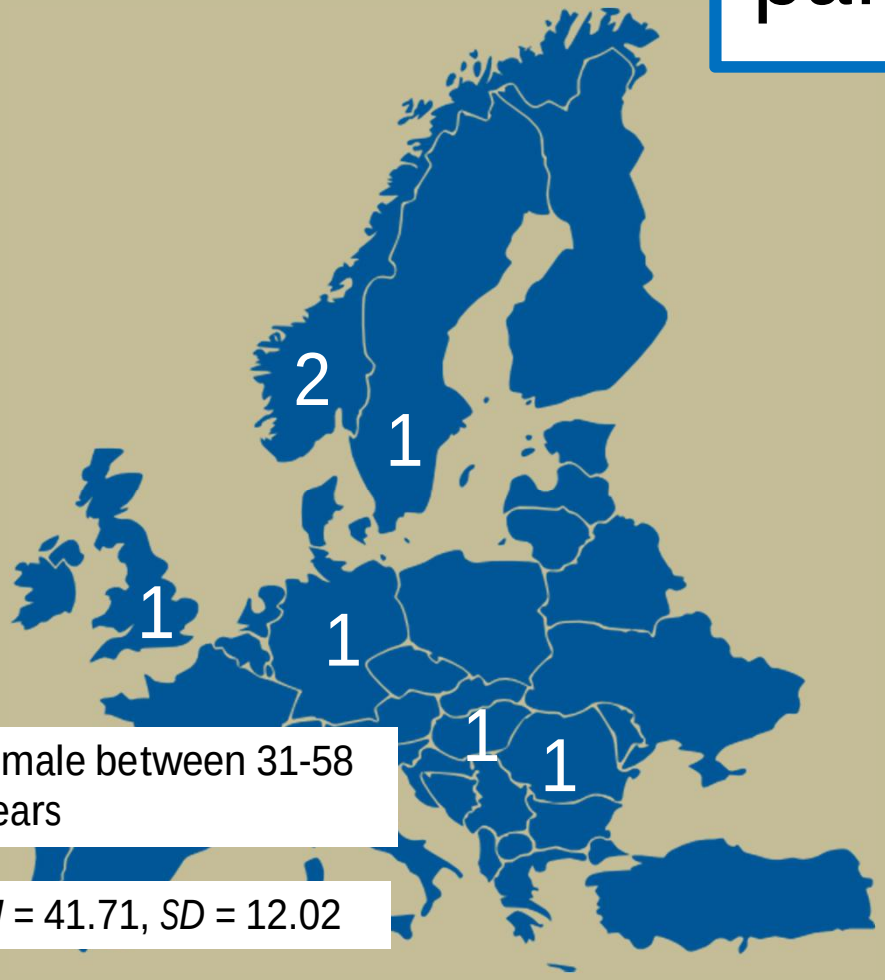


participants

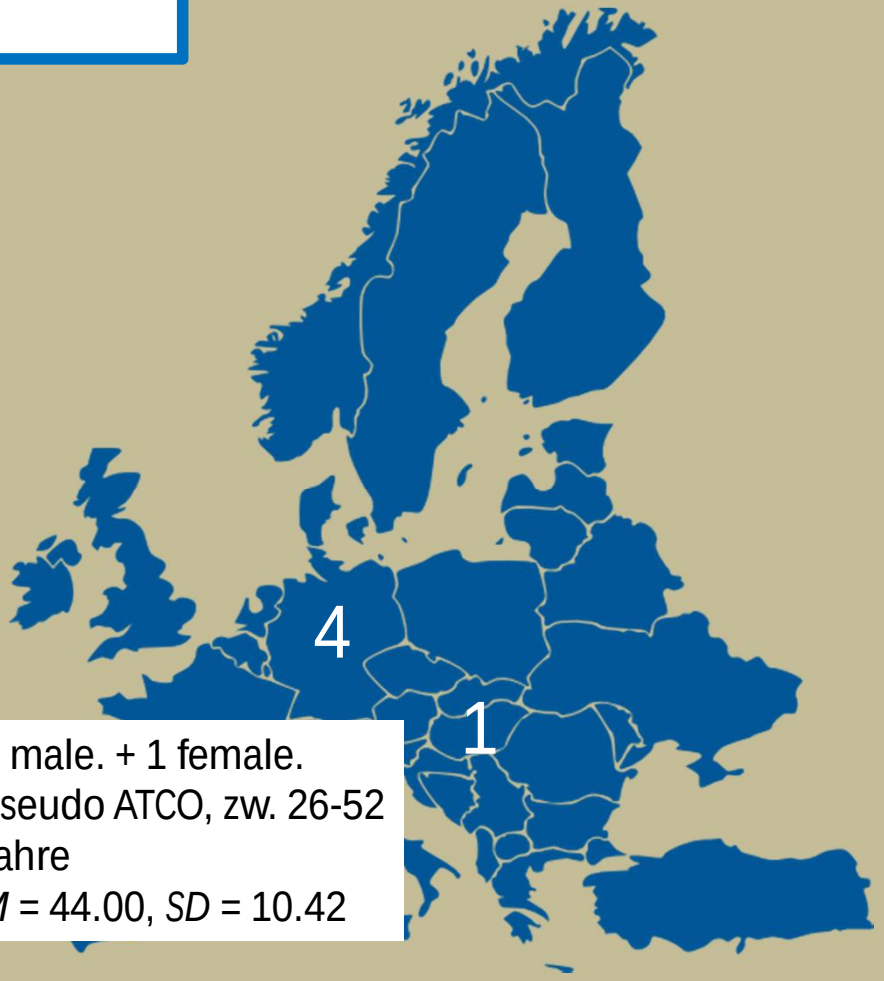
ATCOs



7 male between 31-58 years

M = 41.71, *SD* = 12.02

Pseudo ATCOs



4 male. + 1 female. Pseudo ATCO, zw. 26-52 Jahre

M = 44.00, *SD* = 10.42

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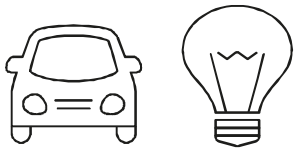
results

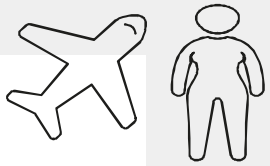
detection tasks

AAMO

„Please look at the white vehicle on the apron. Can you perceive its flashing light in a safe and efficient manner?“



VDT



„D-UG is on an inbound flight. Please focus on the final approach area and press the buzzer as soon as you detect the AC.“

„The man will go to his vehicle soon. Please tell me, when he steps on the runway.“

VTT

„Please watch D-MM performing a Touch+Go and follow it during ist climb. Press the buzzer as soon as you can‘t see it anymore.“

„Please follow the helicpoter on low approach.“

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Detection task protocol

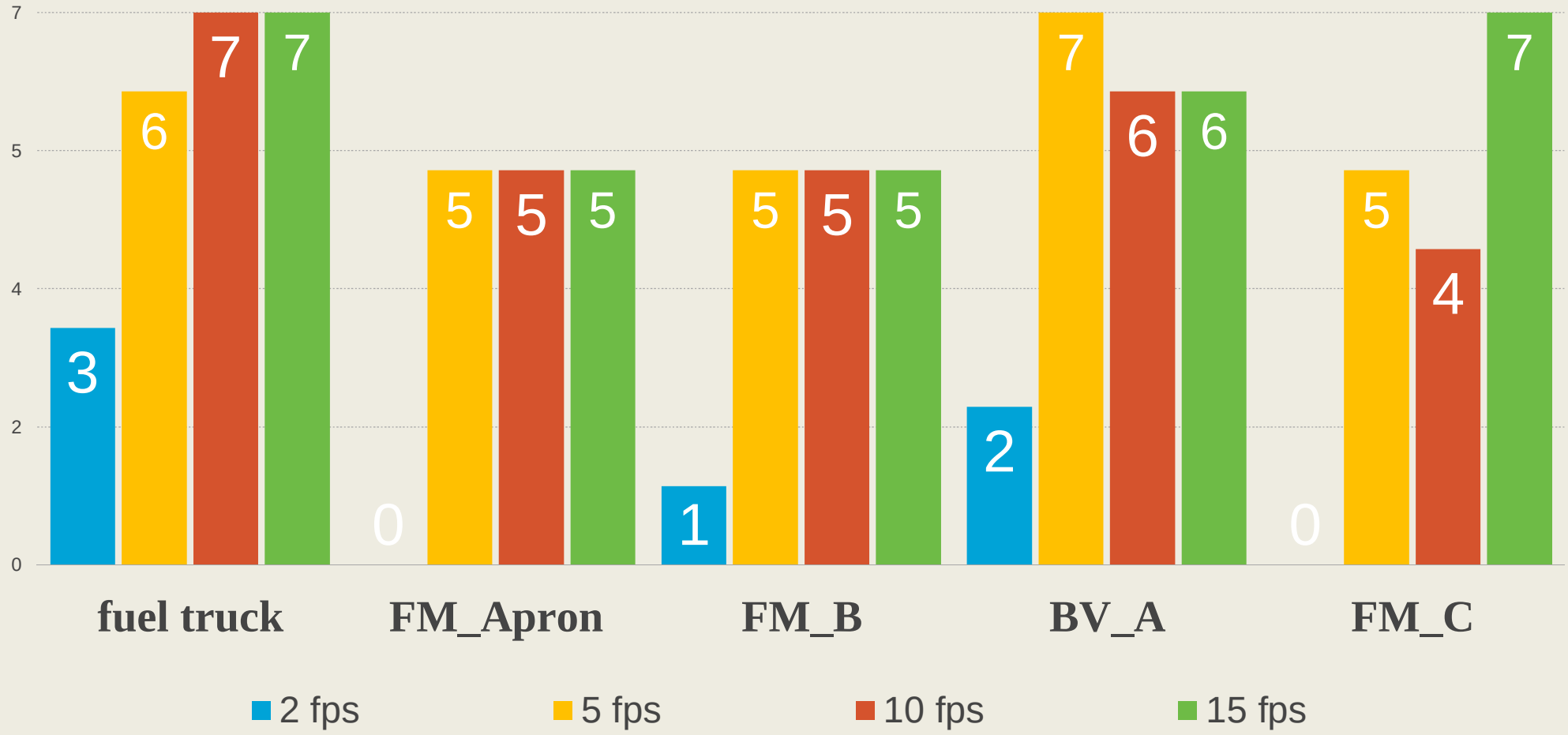
Time	Callsign	N°	Question/Instruction	Q/I Type	Position	Answer	
2.20	D-ERMM	1	A propeller AC on the apron will soon start its engine. ➔ 1. Please show me with your index which one it is. ➔ 2., 3., 4. Can you perceive the movement in a safe and efficient manner?	AAMO	Apron	1	0
2.48	D-UG	2	D-UG is on an Inbound Flight. ➔ Please focus on the final approach area and press the buzzer as soon as you detect the AC.	VDTT	Final Approach	Buzzer	
4.35	Fuel Truck	3	Please look at the Fuel Truck next to the helicopter. ➔ Can you perceive the flashlight in a safe and efficient manner?	AAMO	Apron	1	0
6.50	D-ERMM	4	➔ Look! D-MM just got a taxi clearance and is taxiing via Charlie & Bravo.	VTT	Apron	Standard	

Visual Detection 1/3

Propeller, birds and wind directions remain uneffected.

$\chi^2 = 1$; df = 3; $p < .001$

Performance of Perception of blinking light decreases with 2fps.



Visual detection 2/3

Visual Detection range performance on final remains uneffected.

$\chi^2 = 2.14, df = 3, p = .543$

Learn effects

Visual Detection range performance in traffic curcuit remains uneffected.

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Visual detection 3/3

Visual Detection range performance in departure area remains uneffected.

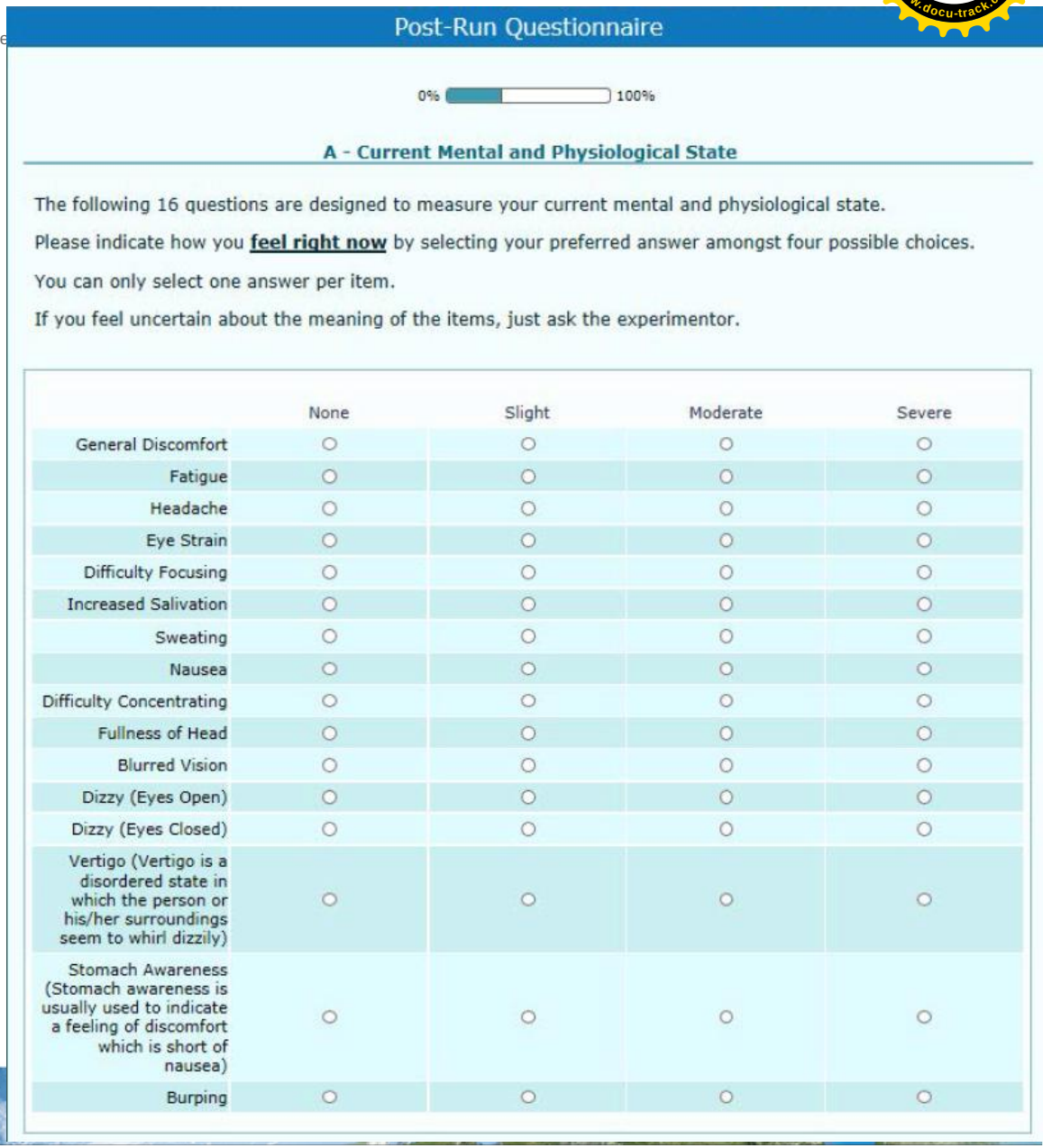
$\chi^2 = 1.8$, df = 3, $p = .615$

Physiological stress 1/4

3 dimensions:

- Nausea
- Oculomotor
- Disorientation

Simulator Sickness Questionnaire (SSQ) by Kennedy, Lane et al. (1993)



Post-Run Questionnaire

0% 100%

A - Current Mental and Physiological State

The following 16 questions are designed to measure your current mental and physiological state.

Please indicate how you **feel right now** by selecting your preferred answer amongst four possible choices.

You can only select one answer per item.

If you feel uncertain about the meaning of the items, just ask the experimentor.

	None	Slight	Moderate	Severe
General Discomfort	○	○	○	○
Fatigue	○	○	○	○
Headache	○	○	○	○
Eye Strain	○	○	○	○
Difficulty Focusing	○	○	○	○
Increased Salivation	○	○	○	○
Sweating	○	○	○	○
Nausea	○	○	○	○
Difficulty Concentrating	○	○	○	○
Fullness of Head	○	○	○	○
Blurred Vision	○	○	○	○
Dizzy (Eyes Open)	○	○	○	○
Dizzy (Eyes Closed)	○	○	○	○
Vertigo (Vertigo is a disordered state in which the person or his/her surroundings seem to whirl dizzily)	○	○	○	○
Stomach Awareness (Stomach awareness is usually used to indicate a feeling of discomfort which is short of nausea)	○	○	○	○
Burping	○	○	○	○

Physiological stress 2/4

- Physiological stress is uneffected of the frame
  - no significant differences between *base* and *treatment* and in between the *treatment levels*
  - $\chi^2 = 5.89$, df = 4, $p = .208$

- All values are extremely under averaged

Physiological stress 3/4

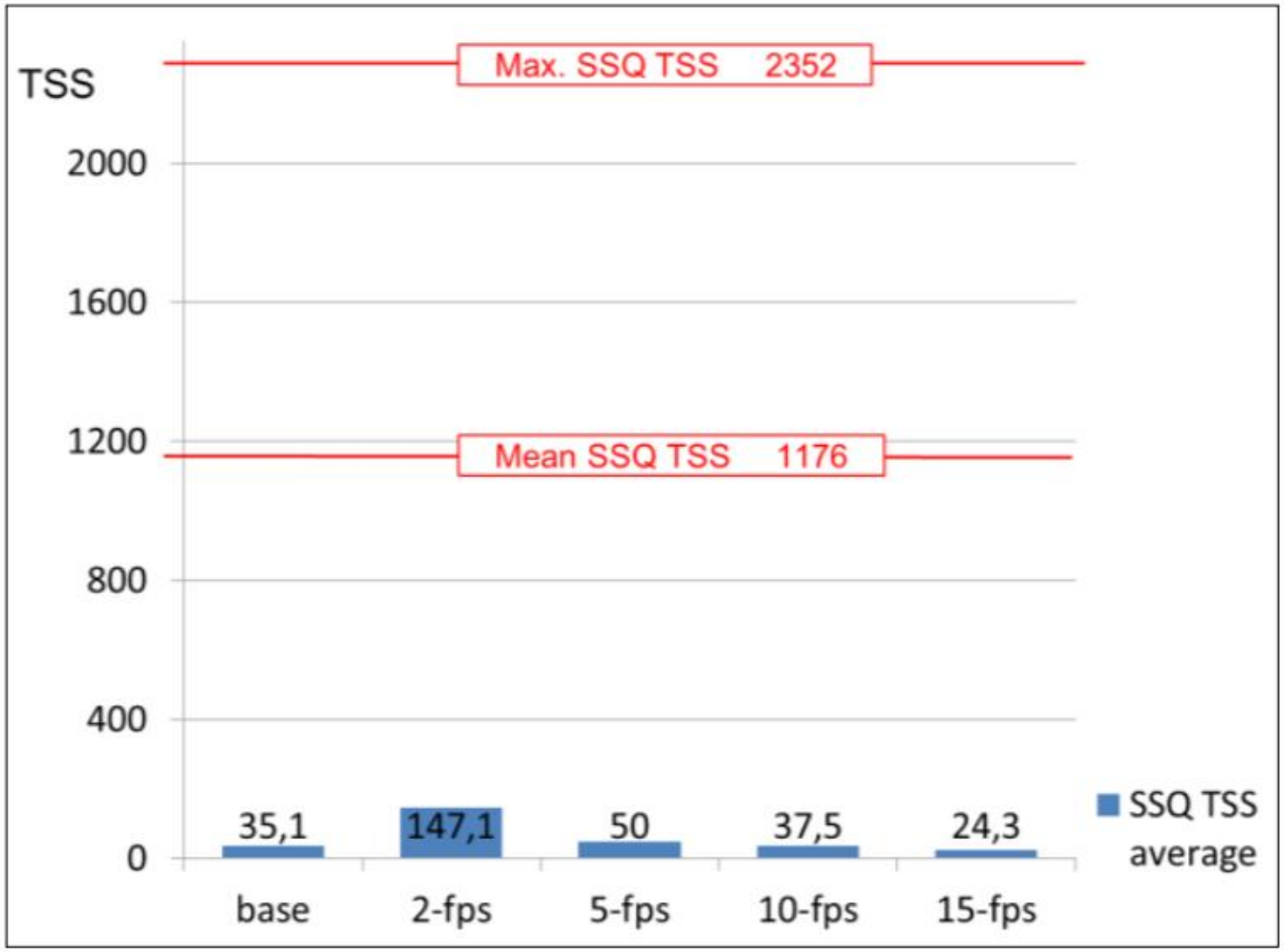


Figure 2. Total Sickness Scores before (base) and for four different FR test conditions.

Physiological stress 4/4

Slightly effected Items:

- Fatigue
- Head ache
- Eye Strain
- Dizzy (open eyes)
- Sweating

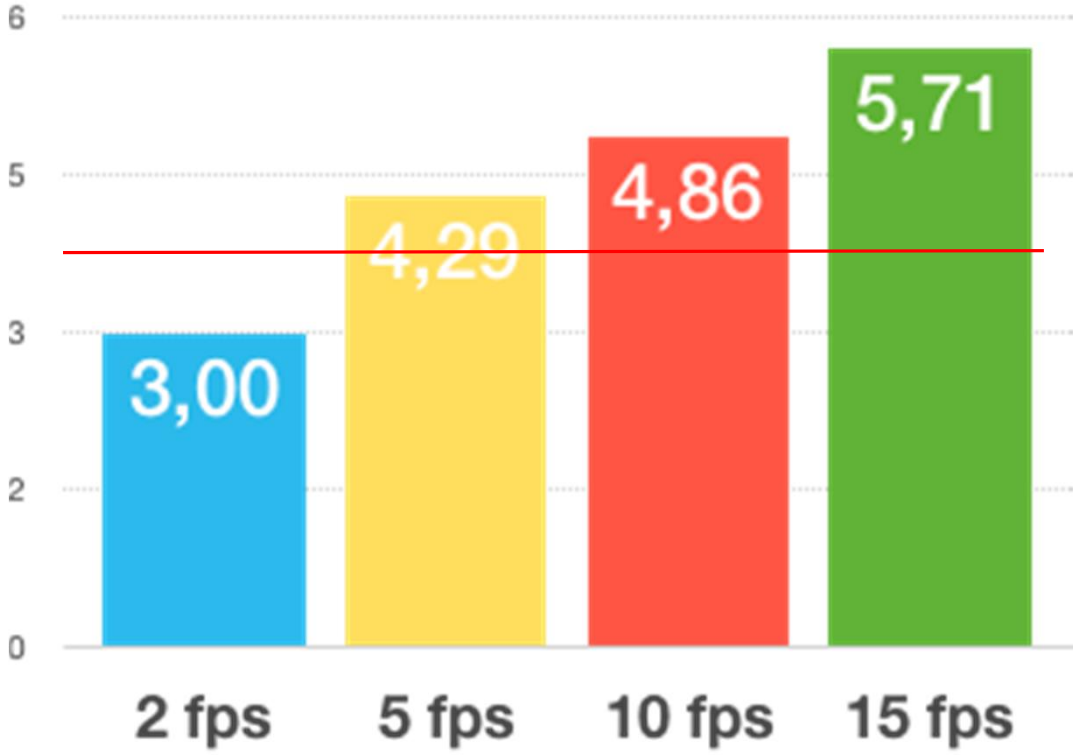
Perceived Video Quality

„Please rate the extent to which you find the given frame rate acceptable.“

Totally unacceptable	Unacceptable	Slightly unacceptable	Neutral	Slightly acceptable	Acceptable	Perfectly Acceptable
○	○	○	○	○	○	○

The perceived Video Quality decreases when frame rate becomes lower.

Only 2fps are estimated as „slightly unacceptable“.



$\chi^2 = 12.05$, df = 3, $p < .01$

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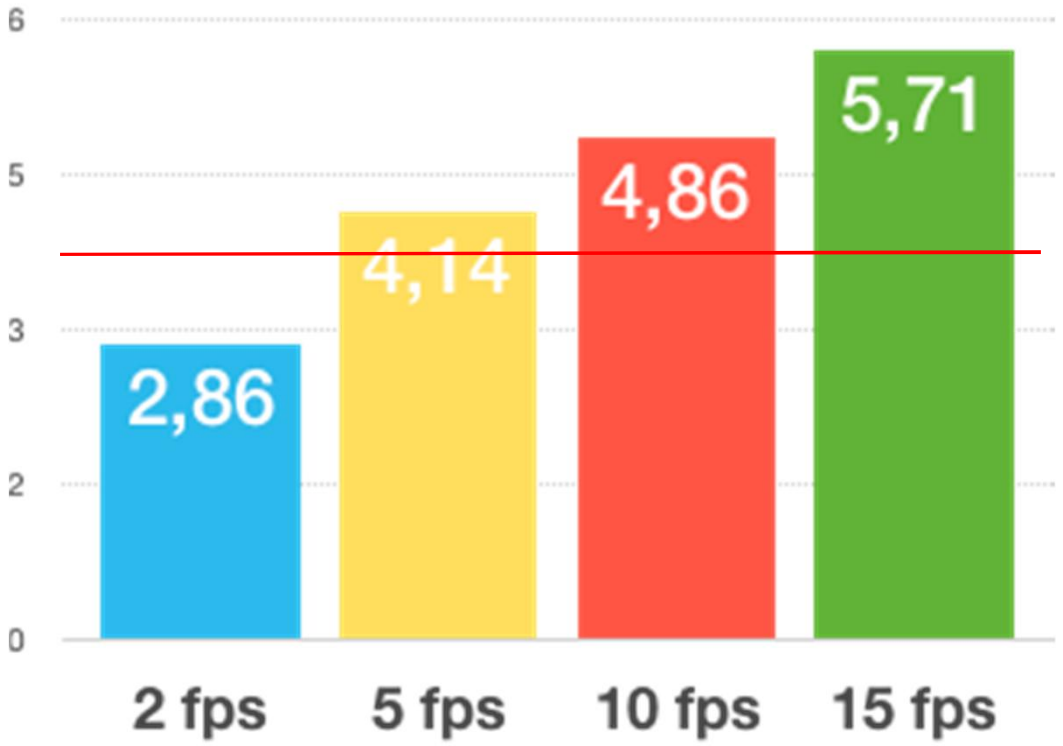
Perceived System Operability

„I would be able to control the traffic in this video with the given frame rate.“

Strongly disagree	Disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Agree	Strongly Agree
○	○	○	○	○	○	○

The perceived System Operability decreases when frame rate becomes lower.

Only 2fps are estimated as „somewhat disagree“.



$\chi^2 = 12.68$, df = 3, $p < .01$

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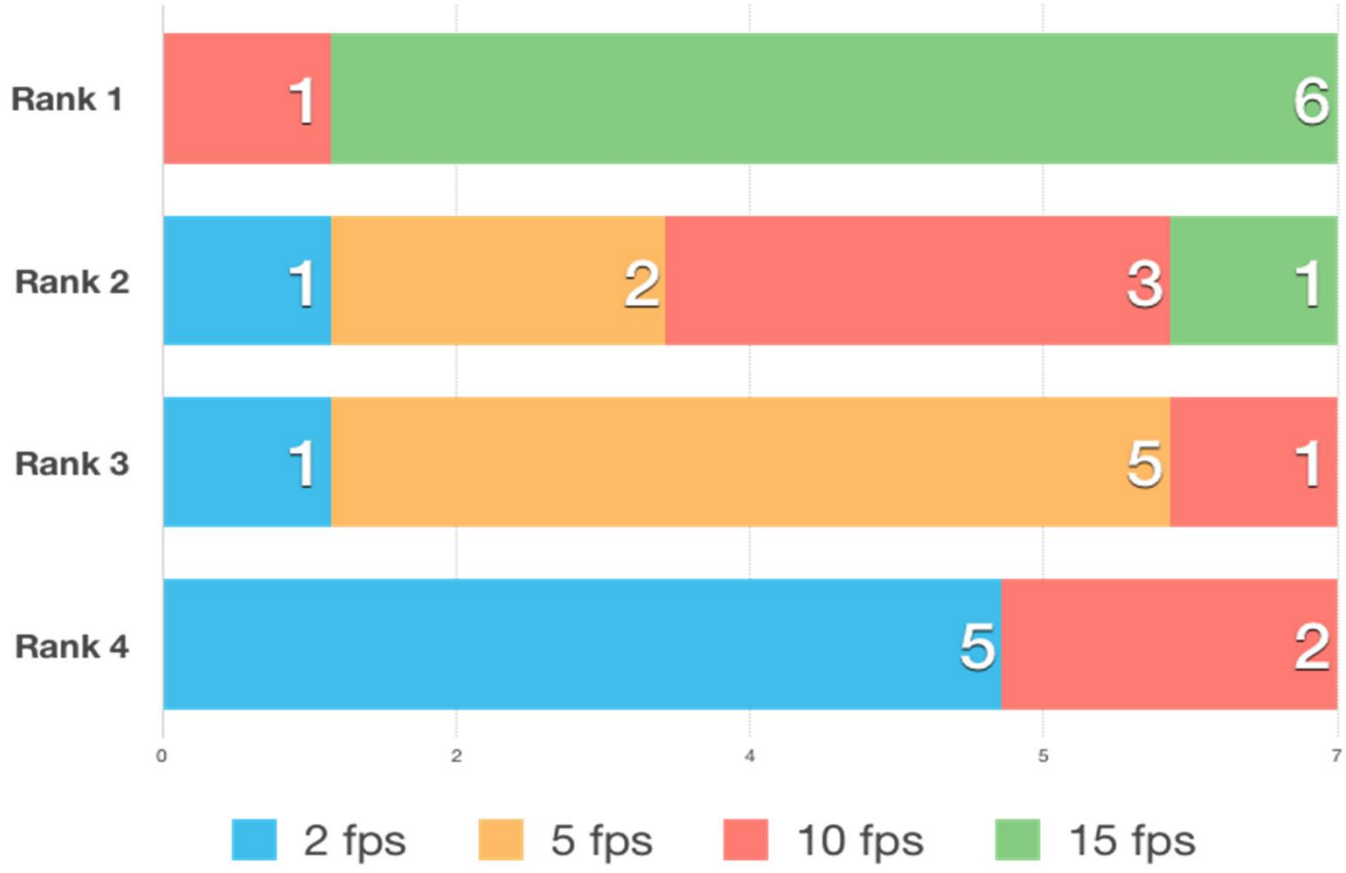
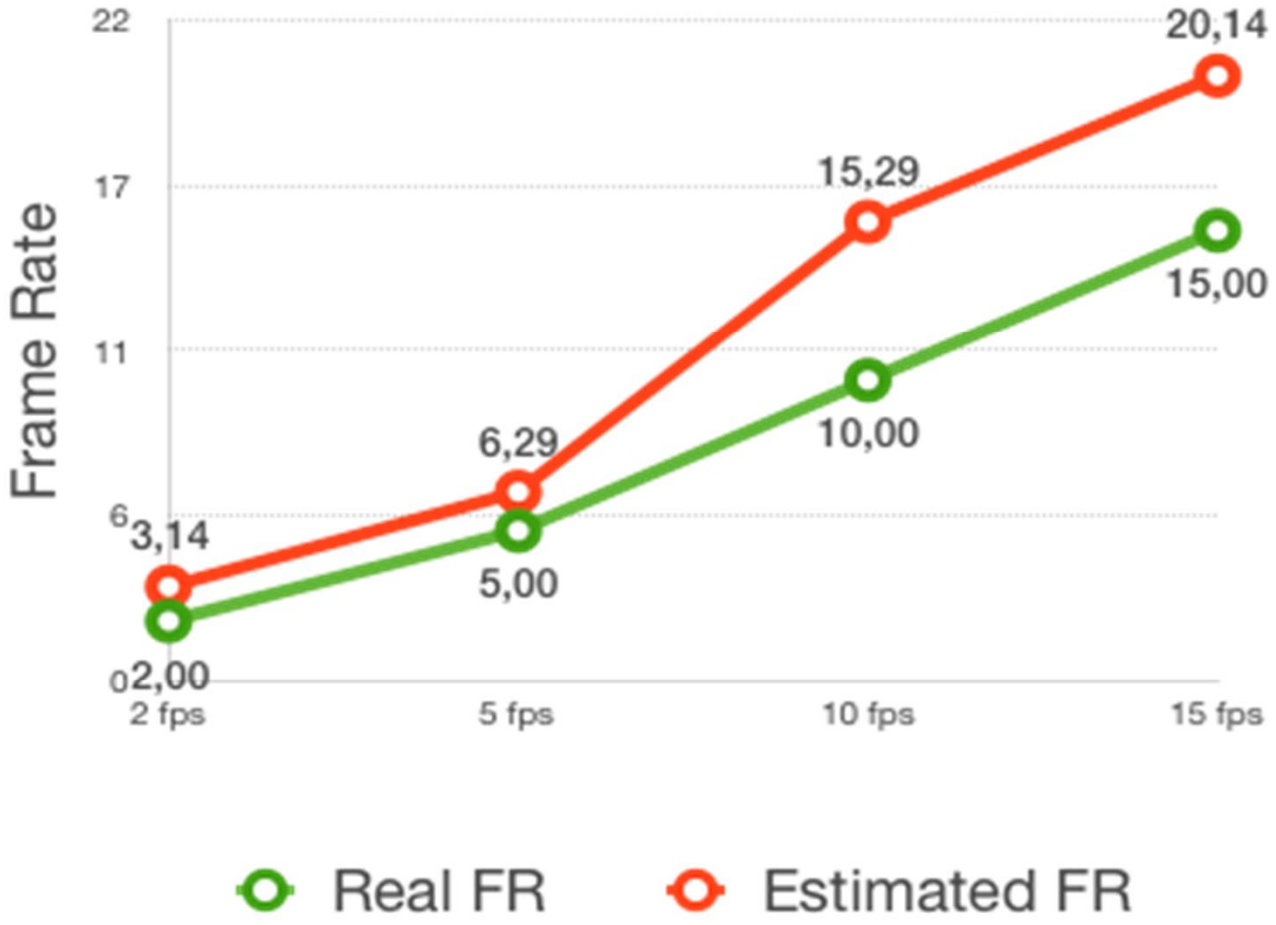
Preferred Frame Rate



Estimated Frame Rate vs. Real Frame Rate



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Conclusions

- Visual detection range performance uneffected
- Check blinking lights performance in < 5 fps conditions

- Physiological stress not affected !

- Preference for higher vs. lower frame rates

- Perceived Operability agreed for 5 /10 / 15 fps but not for 2 fps in this setting

What is still to be done?

Long term studies

Check Blinking lights

Balance Frame Rate with Image Resolution

Match to Sat link capacities

Standar-disation ✓

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Contact:
joern.jakobi@dlr.de
www.dlr.de/fl
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